Search performance using imaging displays with restricted field of view

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Abstract

Search performance using optical imaging systems with restricted viewing area was investigated using a prototype interface and controls of the airborne Enhanced Low-light Level Visible and Infrared Surveillance System (ELVISS). Three different search environments were simulated, one over water, one over land, and one designed specifically to search for objects with retro-reflective properties. Field of view (FOV) of the images from the two ELVISS sensors, a Forward-Looking InfraRed sensor, and an Active-Gated TV was varied. The study suggests that the most effective FOV for search using imaging systems depends on the type of search and/or the sensor mode employed. When using a laser illuminator beam to search for targets with retro-reflective properties, more targets were accurately identified when FOV was wide (20°) than when it was narrower (2°). In other tasks, when the beam was not active, a narrow/wide FOV range of 5° and 20° was more effective than lower (2°:10°) or higher (15°:35°) viewing fields.

Résumé

On a effectué une étude sur l'exécution de tâches de recherche à l'aide de systèmes d'imagerie optique à champ de vision limité en se servant d'un prototype d'interface et de commandes du système perfectionné de surveillance à intensification de lumière visible et à infrarouge (ELVISS), installé à bord d'aéronefs. Trois environnements de recherche différents ont été simulés : un au-dessus de l'eau, un au-dessus du sol et un autre conçu spécialement pour la recherche d'objets ayant des propriétés de rétroréflexion. On a fait varier l'angle de champ des images obtenues avec deux capteurs ELVISS : un capteur infrarouge à balayage frontal et un capteur de télévision commandée par portes actives (AGTV). Les résultats de l'étude portent à croire que le champ de vision le plus efficace pour la recherche à l'aide de systèmes d'imagerie dépend du type de recherche effectué et/ou du mode utilisé pour le capteur. Lorsqu'on utilisait un faisceau d'illuminateur laser pour la recherche de cibles ayant des propriétés de rétroréflexion, on a identifié avec précision un plus grand nombre de cibles avec un champ de vision large (20°) qu'avec un champ de vision étroit (2°). Dans d'autres tâches, lorsque le faisceau n'était pas actif, une combinaison de champs de vision de 5° (étroit) et 20° (large) était plus efficace qu'une combinaison inférieure (2° et 10°) ou qu'une combinaison supérieure (15° et 35°).

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Executive summary

Multi-sensor surveillance systems are being considered for use by Search and Rescue (SAR) specialists to support search at night and under degraded weather conditions. One such display is the Enhanced Low-light Level Visible and Infrared Surveillance System (ELVISS). The ELVISS consists of two sensors: an Active-Gated TV (AGTV) and a Forward-Looking InfraRed (FLIR) imager. The AGTV uses a gated camera and a laser beam to illuminate the scene below, while the FLIR is a passive imaging sensor that produces an image based on temperature variation. The AGTV can also be used in passive mode at which time it functions as a Low-light Level TV (LLTV). Rather than looking out the aircraft window the operator uses a camera and sensor to search the terrain below and must rely on information gathered from a display with restricted Field of View (FOV). Thus, the overall picture of the scene is restricted in comparison to the pilot's view from the aircraft window and the impact of limiting FOV becomes an important issue. For example, if the system is equipped with the option, a wide FOV is usually preferred for detection purposes and a narrower setting for identification. However, a trade-off exists between FOV, image resolution, and magnification. If FOV is too narrow, targets may go undetected simply because they do not fall into view. Alternatively, if FOV is too wide, targets may be impossible to classify because the images are too small and magnification insufficient.

Field of view, as it relates to performance on search tasks using imaging displays with restricted FOV, was studied. Sensor FOV was investigated with three different simulated search environments using a prototype interface for the ELVISS. Participants in the study used the sensor cameras on the prototype, controlled by a single joystick, to search for targets in the terrain. Field of view of the sensor images was varied and performance was measured as the number of correctly identified targets. The three scenes included a scenario over a large expanse of water, another over land, and one specifically designed to search for targets with retro-reflective properties.

In general, the results suggest that the most effective FOV for search tasks using images with restricted FOV depends on the type of search and the sensor employed. When using the AGTV illuminator beam to search for targets with retro-reflective properties, more targets were accurately identified when FOV was wide (20°) than when it was narrower (2°). In other tasks, where the beam was not active, a FOV range of 5° and 20° was more effective than lower (2°:10°) or higher (15°:35°) viewing fields. The method by which FOV is changed was also investigated. Comparing continuous zoom to a discrete method of switching FOV, the results tended to support the continuous mode although we conclude that, like FOV, the most effective method is likely a function of the characteristics of the search itself as well as the image presented on the interface.

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Sommaire

On envisage la possibilité de faire utiliser des systèmes de surveillance multicapteurs par les spécialistes en recherche et sauvetage pour les appuyer dans l'exécution de leurs tâches pendant la nuit et dans des conditions météorologiques difficiles. Parmi ces systèmes, on compte le système perfectionné de surveillance à intensification de lumière visible et à infrarouge (ELVISS), qui est composé de deux capteurs : un capteur de télévision commandée par portes actives (AGTV) et un imageur à balayage frontal (FLIR). Le capteur AGTV utilise une caméra commandée par portes et un faisceau laser pour éclairer la scène au-dessous, alors que l'imageur FLIR est un capteur d'imagerie passif qui produit une image à partir de la variation de température. Le capteur AGTV peut aussi être utilisé en mode passif; il fonctionne alors comme un capteur de télévision à bas niveau de lumière (LLTV). Au lieu de regarder par la fenêtre de l'aéronef, l'opérateur utilise une caméra et un capteur pour examiner le terrain au-dessous, et il doit s'appuyer sur les données présentées par un affichage à champ de vision limité. Par conséquent, l'image globale de la scène est plus restreinte que celle qu'obtiendrait le pilote en regardant par la fenêtre de l'aéronef, de sorte que la restriction du champ de vision est un facteur d'une grande importance. Par exemple, lorsqu'un système permet cette restriction, un champ de vision large est habituellement préférable aux fins de la détection et un champ étroit est préférable aux fins de l'identification. Cependant, il existe un compromis entre le champ de vision, la résolution de l'image et le grossissement. Lorsque le champ de vision est trop étroit, des cibles peuvent être manquées simplement parce qu'elles ne sont pas comprises dans le champ de vision. Par contre, lorsque le champ de vision est trop large, certaines cibles peuvent être impossibles à classifier parce que les images sont trop petites et que le grossissement est insuffisant.

On a effectué une étude du champ de vision en rapport avec l'exécution de tâches de recherche à l'aide d'affichages d'imagerie à champ de vision limité. On a étudié le champ de vision des capteurs dans trois environnements de recherche simulés différents en se servant d'un prototype d'interface pour le système ELVISS. Les participants de l'étude ont utilisé les caméras de détection sur le prototype, avec commande à l'aide d'une seule manette, pour effectuer la recherche de cibles sur le terrain. On a fait varier le champ de vision des images des capteurs et on a mesuré l'efficacité sous la forme du nombre de cibles correctement identifiées. Les trois scènes comprenaient un scénario au-dessus d'une grande étendue d'eau, un autre au-dessus du sol et un autre conçu spécialement pour la recherche d'objets ayant des propriétés de rétroréflexion.

En général, les résultats de l'étude portent à croire que le champ de vision le plus efficace pour la recherche à l'aide d'images à champ de vision limité dépend du type de recherche effectué et du capteur utilisé. Lorsqu'on utilisait le faisceau d'illuminateur AGTV pour la recherche de cibles ayant des propriétés de rétroréflexion, on a identifié avec précision un plus grand nombre de cibles avec un champ de vision large (20°) qu'avec un champ de vision étroit (2°). Dans d'autres tâches, lorsque le faisceau n'était pas actif, une combinaison de champs de vision de 5° (étroit) et 20° (large) était plus efficace qu'une combinaison inférieure (2° et 10°) ou qu'une combinaison supérieure (15° et 35°). On a également étudié la méthode de modification du champ de vision. Les résultats de la comparaison d'une méthode à zoom

continu et d'une méthode discrète de modification du champ de vision tendaient à appuyer le mode continu, même si nous sommes arrivés à la conclusion que, comme dans le cas du champ de vision, la méthode la plus efficace dépend vraisemblablement des caractéristiques de la recherche elle-même ainsi que de l'image présentée par l'interface.

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Background

The search and rescue (SAR) operator, conducting a search operation from the aircraft window, relies on his or her own expertise and on conditions conducive to good visibility. The optical imaging sensor system provides a means of enhancing the search scene in a number of ways, improving visibility of the terrain so that a search operation can potentially continue under conditions that otherwise might call for early termination.

One optical imaging system under development is the Enhanced Low-light Level Visible and Infrared Surveillance System (ELVISS), which is made up of two sensors: an Active-Gated TV (AGTV) and a Forward-Looking InfraRed (FLIR) imager. The AGTV requires no ambient light to be effective and the active gating feature permits shuttered control of light returning to the camera from a laser illuminator. By setting the range and distance of the illuminator beam, and gating the shutter aperture, the return of light to the camera is controlled and the effects of backscattering from haze, snow, or rain, and the presence of scattered light from artificial sources, like street lamps, significantly reduced. As a result, the system can continue to provide adequate image contrast and resolution under degraded weather conditions or where natural illumination is not available. In passive mode the sensor can operate as a Charge Coupled Device (CCD) camera that relies on visible light at least to the level of moonlight and that uses a light-sensitive integrated circuit to store and display image data. The second sensor, the Forward-Looking InfraRed, is a thermal imager that detects mid- and far-infrared radiation and produces an image based on temperature variation. FLIR systems perform adequately under conditions where visibility is degraded but they do not perform well when there is little or no thermal contrast, in the rain for example. The combined capabilities of both sensors (AGTV and FLIR) will enable search missions to continue in environments and conditions where they might otherwise be terminated.

The two sensors are slaved together and view the same scene and are controlled by a single user interface located in the aircraft. The operator uses a joystick to direct the cameras across the terrain and the two video images are displayed separately on the interface (see Figure 1). Part of the interface is taken up by a moving map display and below the moving map is a freeze frame area for storing still images. Overlays on the display provide information regarding the status of the system.

Operating a multi-sensor optical imaging system is a complex procedure. A single operator must attend to large amounts of information and manage multiple controls and functions while searching a video image and directing the camera across the moving terrain. The task is further complicated by the need for the operator to maintain situational awareness in a constantly moving scene, not only with respect to his own position in relation to the world, but also in terms of his view in relation to that of other crew members who see the scene from a very different perspective. While the operator views a video image and uses an adjustable camera, the pilot and other crew members observe the terrain from the aircraft window following the line of sight of the aircraft. The mental representation of the world from each of these viewpoints is constructed using different knowledge bases (Wickens & Prevett, 1995). The pilot references the world from a forward-looking, or ego-referenced position. The operator, on the other hand, uses a world-referenced knowledge base, gathered from the image display, to define the relationship between his own position and the position of the aircraft, as well as that of the camera footprint.

A direct result of viewing imagery projected on a screen is that FOV of the scene is severely restricted, being limited by the capabilities of the sensor and by the physical area available for displaying the image. As a result, the picture seen by the system operator is not only from a different perspective, but is also much smaller than the window view observed by other crew members. Apart from size and perspective, other issues associated with viewing a video image include the properties of a monochrome display and the clarity of the image. The trade-off between FOV, resolution, and magnification of the display is well recognized (Warner & Hubbard, 1992; Vos, 1990). For example, enlarging an object through magnification results in a loss of FOV, and thus a reduction in the area available for searching. If FOV is narrow, targets may go undetected simply because they do not fall into view on the screen. Furthermore, magnification might be so high that it is difficult to discriminate the target from the background. Alternatively, if FOV is wide, targets may be impossible to find or recognize because the images are too small.

One might presume that being able to vary the FOV of the optical imaging system would resolve some of these limitations. Indeed, variable FOV does give the operator control over some characteristics of the sensor image and undoubtedly has advantages, but it does not solve all the problems. Given the option, the operator will typically use a wide FOV for detection purposes and a narrower setting for identification (Rabin, 1994). Since quick and accurate response is critical to the successful outcome of a search mission it is essential that time is not wasted investigating something that is not a target. What is visible under a wide FOV may fall out of view when the area is reduced. If the operator loses contact, even temporarily, additional search time may be required, jeopardizing the mission. The chance of losing sight of a target is increased when one considers that the aircraft, and therefore the display image, is constantly moving. Under these ever-changing conditions, attempting to relocate a previously detected target using a narrow FOV can be particularly disorienting to the operator.

Other factors embedded in the search procedure interact with restricting the FOV of an image. Keeping in mind that increasing the camera's rate of movement, or slew rate, does not necessarily translate into increased detection rate, the operator must ensure that the rate and path of the camera's sweep are regulated to cover enough area so that there is a high probability of the target falling into view, but not so much that the potential for detecting possible targets is reduced because the slew rate is too high. A narrow FOV provides a smaller scene area to be covered by the camera. Should a target be present in the image, it will remain visible on the display screen for less time than a wider FOV image. Thus, slew rate should increase as FOV decreases so that the entire image can be covered before the target potentially moves off the screen. On the other hand, by increasing FOV the chance that the operator has in fact searched the area, regardless of whether or not it has been passed over by the camera, is potentially reduced.

The interface associated with an optical imaging sensor system has a direct impact on the operator's perception of the world and on his ability to use the system easily and effectively. As quick response time is vital to the successful outcome of any search mission, and, given that minimizing false alarms can ultimately lead to reduced response time, a display that provides for accurate and rapid target detection and identification will have significant benefits to the overall success of a SAR operation. Determining the impact of FOV on the operator's task and the characteristics of the sensor display that affect FOV are issues in need of investigation. The goal of the present work was to empirically evaluate FOV as it relates to airborne search where the scene is viewed from an images with restricted FOV.

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Current research

Previous investigations of FOV and air-to-ground search have used real world scenes in the form of print originals, slides developed from print, or projected video, as a way of presenting the scene to be searched. These methods exclude the functionality of a surveillance sensor and the interactive role of the operator with the scene and with the rest of the SAR crew. In studies that have used computer generated simulated flight scenarios to investigate target search and FOV, participants have not often been given control of movement within the terrain. If they have it has been from the viewpoint of the pilot flying the aircraft rather than from the perspective of an operator directing a camera across the scene. With sensor surveillance systems such as the ELVISS, by using a joystick to direct the camera, the operator has control of the area to be searched in so much as is feasible under the constraints of the sensor and the flight path of the aircraft.

Whether any specific FOV, or range of FOV, facilitates the search process is difficult to define, mainly because the answer depends on several factors, many of which are inherent in the scene and in the task performed, as well as in the way performance is assessed. Past research is inclined to vary on all these points resulting in a plethora of results. Ruiss and Snyder (1965), for instance, examined FOV in a search paradigm by embedding targets into moving, real-world images, rear-projected, and relayed to a monitor by a forward-looking TV camera. A hand-held switch and a pointing stick were used to indicate recognition and the position of targets in the scene, and FOV was varied by changing the lens of the TV camera. The number of correctly identified targets increased as FOV increased across 8.2°, 10° and 34°, while the range at which targets could be identified decreased. Also, larger targets were identified more accurately than smaller ones. With respect to errors, more targets were missed as FOV decreased, and small targets were more likely to be missed than larger ones. However, the proportion of objects incorrectly classified as targets was not affected by FOV. These results suggest that searching a scene with a wide FOV promotes a more productive, and accurate, search. It is possible that the outcome simply illustrates that objects remain in sight for longer periods of time when viewed with wider FOV and, as a result, have more of a chance of being detected. Also, these results cannot be generalized to search performance with a system like the ELVISS because, in that study, the scene moved at a constant rate and subjects had no control over movement within the scene or how long targets remained in view.

Other researchers have found that wider FOV is not always better (Turner, 1984). In a flight simulation, pilots wore a Helmet-Mounted Oculometer System (HMOS) with an Area-of-Interest (AOI) display to navigate through a canyon and search for targets along the way. An AOI display is a small, high resolution area of the scene, often inset into a surrounding low resolution periphery. The AOI used in this experiment was attached to an eye-slaved visual imaging system, designed to change the scene on the display in conjunction with the wearer's eye movement. Thus, pilots were able to select a particular area of the scene they wished to focus on. They also had control of lateral movement of the aircraft, but were unable to vary altitude or speed. Three FOV of the AOI were evaluated, 12°, 18° and 28°, and the results demonstrated that more targets were missed with the smallest and largest FOV compared to the intermediate level of 18°. As well, as part of the task pilots were instructed to maintain a flight path as close to the centre line of the course as possible and the data showed that there was less deviation from the course with the 18° FOV display. This work demonstrates that an intermediate FOV can be more beneficial for target detection than wider or narrower levels, at least when there is no option to change FOV during the search. Other work found contrasting results. Pilots, using a standard computer display to navigate through a slalom course in a flight simulator, were more accurate in flying the course using a wide FOV of 55°, compared to a narrower viewing area of 25° (Bricker & Foyle, 1990). In fact, they were three times more likely to hit the course pylons when flying with the narrow FOV. One important difference between these two studies was the task performed by the participant which suggests that this is a significant factor with respect to FOV.

Warner and Hubbard (1992) used a threshold detection task to examine image resolution and FOV. A threshold level was established for detecting target characteristics by having participants use a hand-controller to adjust the distance to the target until specific features were visible or not visible. Like Turner's work (1984), the task was performed in a flight simulator using the center screen only of an AOI display. Threshold detection distance was found to be greater for the narrow FOV, 26° with high resolution, than for a wider, low resolution FOV of 40°. The results are not surprising, given the importance of resolution to detection, and the relationship suggests that performance should continue to improve as FOV is decreased. However, this was not the case for Turner's search task.

All of these studies were designed to assess FOV for image displays with restricted viewing area but the diversity of the experimental designs, and of the results, indicates that there is no easy way of setting a standard FOV for these sorts of displays. To research FOV for imaging sensor system displays the evaluation must simulate as closely as possible the environment of the surveillance operator. Relevant factors include tasks that are appropriate to the search operation as well as the way the scene is presented to the search technician. With the advent of computer generated imagery, realistic simulations of landscapes and targets can be produced, allowing not only for the application of specific features in the scene, but also for the experimental manipulation of scene and target variables. The present study used synthetic, computer generated imagery to simulate real world terrain viewed from an aircraft in flight. Combined with a prototype of the ELVISS interface and controls a simulation of the search operator's task using an airborne optical imaging sensor system was created.

Search and rescue missions cover diverse environments, from searching for a missing vessel in a vast expanse of water to locating a downed aircraft in dense forest. Three different airborne search scenarios were simulated in this study: one over a large area of water, one over land, and one specifically designed to search for objects with retro-reflective properties. The scenarios were designed to consider the diversity of the search and rescue environment while assessing the impact of the choice of FOV as it relates to the capabilities, and possible limitations, of a sensor system such as ELVISS. Each scenario was evaluated independently.

Water scenario: The FLIR sensor on the ELVISS supports a discrete, narrow/wide, FOV function whereas the AGTV is equipped with a continuous zoom ranging from .5° to 40°. The water scenario focused on determining the best FOV combination for the FLIR sensor when coupled with the zoom of the AGTV. For a SAR technician a search mission over water can be the most difficult, primarily because it involves searching for a single, small object over an incredibly vast expanse of uniform background. Moreover, vessels on the water are relatively hard to discriminate from a distance and it is often necessary to inspect every potential target at close range. Thus, a large portion of a search mission over water is spent vigilantly scanning an area from a wide angle, with the aircraft intermittently descending and circling over a potential target location for closer scrutiny. Under certain conditions, in a busy pleasure vessel region, for example, this procedure is recurrent and time consuming.

The water scenario used in this study was designed to simulate such a search, over a large body of water while inspecting many potential targets at close range. Subjects were instructed to use the FLIR sensor for target search and detection, and to use the zooming function on the AGTV for identification purposes. The FLIR sensor was equipped with a discrete FOV which could be set to wide or narrow and the subject was informed that they could forego using the AGTV zoom if they found the range of settings on the FLIR to be adequate for identifying. However, the zoom of the AGTV covered a wider range of FOV than the discrete levels of the FLIR and it was anticipated that most of the time subjects would have to use the AGTV to accurately classify an object.

Retro-reflective scenario: The AGTV sensor supports a laser illuminator beam and a gating mechanism on the camera that generates a high-powered capability to detect objects that possess retro-reflective properties. This functionality has been demonstrated in field trials where it was possible to detect a piece of retro-reflective tape, 5 centimetres (cm) x 15 cm, from a distance of 8 kilometres (km) using the AGTV. The retro-reflective scenario was designed to simulate this specific characteristic by evaluating the detection of targets with retro-reflective properties using the AGTV illuminator beam as a function of the FOV of the illuminator beam. Three different FOVs were examined – 2°, 10° and 20°. The AGTV was the only sensor used in this scenario and therefore was the only window visible on the interface. Although FOV was manipulated between experimental sessions, participants were not able to change FOV of the illuminator beam during the run. They were, however, able to use the zoom function to change FOV of the full scene.

Land scenario: A third scenario, over land, in which targets were located amongst other objects that were similar in appearance, was created. Therefore, close inspection was required to identify a target. In this scenario participants used the FLIR sensor , with discrete narrow/wide FOV, and the passive LLTV with continuous zoom. The objective was to compare performance for discrete and continuous zoom using the same range of FOV on each. To mimic the distinct properties of each sensor some targets were visible in the FLIR window only, while others were visible in the LLTV window only, and others were visible in both windows.

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Experiment 1

Method

Participants

Eighteen volunteers participated in two 90-minute sessions. Most of the participants were employees of DRDC Toronto but some were recruited from the general public. They were tested for acuity and contrast sensitivity and all had normal or corrected-to-normal vision.

Apparatus

The experiment was conducted in a room with normal temperature (~20º C) and the lighting dimmed to 13 lux measured with a Hagner Universal Photometer. The simulation was presented on a Silicon Graphics Octane using a 21" monitor and the participant was seated approximately 60 cm from the screen. The primary components of the interface are shown in Figure 1. Each sensor image is represented in a different window, the upper window displaying the AGTV image and the lower window the FLIR. Also, a digitized moving map display is located in the upper right-hand section of the interface providing a topographical map of the terrain at a scale of 1:250,000. The moving map display also shows the direction and position of the aircraft, the footprint of the camera and the direction it is pointing, and the area on the ground already passed by the camera. Below the moving map is a freeze frame area for storing up to six still images of the scene. This feature was not used in this study, but, when used, images are recorded by pressing a button on the joystick when the cursor on the moving map is over the location of interest. The resulting screen capture remains available to the operator for further inspection at any time during the flight.

The participant was not able to control the flight path of a scenario but the direction of the camera was under his or her control by way of a standard joystick, which was placed directly in front, at desk height. There are several functions on the joystick: a trigger switch can be used to engage the auto-tracker; a momentary switch to mark objects in the scene; an auto-slew button that slews the camera back to the aircraft heading; and a primary window switch button which changes the viewfinder frame from the AGTV to the FLIR window. The joystick was operated with the right hand. Two small joysticks were located on a control panel to the left of the main joystick and both were operated with the left hand. The small joystick on the far-left provided the continuous zoom for the AGTV – the joystick could be pushed forward to zoom in and pulled back to zoom out. The small joystick on the near-left provided either a continuous zoom or a discrete FOV function, depending on the experimental parameters, for the FLIR sensor. The discrete FOV function on the FLIR was controlled by a rocker switch on top of the joystick – pushing to the right allowed the participant to set FOV to narrow, while pushing to the left changed the FOV to the wider setting.

In all scenarios the task was to search for targets in the scene by directing the camera across the terrain. Objects identified as targets were to be marked by pressing the red designate button on top of the primary joystick.

Stimulus

The terrain representation used in the simulation was the ‘Certain Impact’ database. The visual image the participant saw was the surface of the land as seen from the aircraft. There was no cloud cover visible. Stimuli in this experiment consisted of vehicles from the FACETS models library (CG^2 Incorporated, 2001). Vehicles included Hummer land vehicles, T72 Tanks, Leclerc Tanks, and Trucks. Geometric Shapes (diamonds, pyramids, cubes, and cylinders) were also used in some of the experiments. If required, stimuli could be given a single digit identifier number or letter, and could also be assigned a retro-reflective patch which would appear directly above the object. The values chosen for speed and altitude of the aircraft may be different in each scenario in order to create an appropriately level of difficulty for the search task. Note that aircraft speed and altitude do not necessarily represent precise, realistic values.

Three different scenarios were simulated: i) one over a large body of water; ii) one searching for targets with retro-reflective characteristics; iii) and one searching for targets on land.

Water Scenario

In the water scenario, the flight path of the aircraft followed a shoreline at approximately a mile and a quarter inland. After flying the shoreline flight once, the plane returned along the same path to the starting point, but on the second pass, the plane flew at approximately one-quarter mile inland. Altitude of the aircraft was set to 500 feet, and speed 100 knots. The moving map display was represented at a scale of 1:250 000. Stimuli, which were visible in both the AGTV and FLIR windows, consisted of 12 target and 12 non-target geometric shapes, each with a three-digit identifier number. The number “368” was designated as the target identifier. Non-targets consisted of any other combination of three numbers from the set 0, 3, 6, 8, and 9. Participants were instructed to use the wide FOV setting of the FLIR sensor for detecting targets and to change to the narrow setting, or use the AGTV continuous zoom to identify the object. To promote use of the FLIR for initial searching the contrast between targets and terrain was higher in the FLIR window than in the AGTV, and therefore targets and non-targets were easier to see in the FLIR. Table 1 shows the luminance values of the targets, non-targets and terrain. To minimize the effects of practice three different versions of the scenario were created using the same flight path and number and type of targets and non-targets, and differing only in the location of the targets and non-targets within the scene. A total of 12 targets and 12 non-targets were placed in each version. The narrow and wide discrete FOV values for the FLIR sensor varied in each experimental session, and were: 2°:10°; 5°:20°; 15°:40°. Because of system limitations, the AGTV was always in continuous zoom mode with a FOV range of .5° to 40°. The AGTV illuminator beam was set to a FOV of 10°.

Retro-reflective scenario

In the retro-reflective scenario stimuli were geometric shapes with retro-reflective markers attached to them and were visible in the AGTV window only. The marker was a small patch that became visible by increasing the luminance when it entered within the beam of the laser illuminator. The flight path across land was a creeping line pattern and the aircraft flew at an altitude of 1000 feet, travelling at a speed of 120 knots. The moving map display was set to a scale of 1:250 000. Targets consisted of 6 geometric cylinders and non-targets were 6 geometric cubes. The cylinders and cubes had a retro-reflective patch that was only visible when it was caught in the AGTV illuminator beam. See Table 2 for luminance values of the targets and non-targets, the retro-reflective patch, and the terrain. To avoid possible effects of practice, three different versions of the scenario were created using the same flight path and number and type of targets and non-targets, and differing only in the location of the targets and non-targets within the scene. The FOV of the AGTV illuminator beam varied in each experimental session being either: 2°; 10°; or 20°. The FOV of the entire scene could be changed by the zoom function that had a range of .5° to 40°.

Land scenario

In the land scenario, stimuli were tanks, trucks, and Hummer land vehicles selected from the FACETS models library (CG^2 Incorporated, 2001). The flight path was a creeping line pattern and the plane flew at an altitude of 1000 feet, and at a speed of 120 knots. The moving map display was set to a scale of 1:250 000. Targets were Hummer land vehicles, while non-targets were tanks and trucks. Targets and non-targets were organized in 12 clusters of groups of 3 and were placed in the terrain so as to appear slightly buried in the ground. The purpose of partially burying clusters of targets/non-targets was to make the task more difficult by reducing the 'pop-out' effect of a stand-alone, single vehicle in the scene. Half of the clusters contained one target in the group, while the other half had no targets, making a total of 6 targets and 28 non-targets. Table 3 shows luminance values for the targets and non-targets and for the terrain. Participants used the LLTV and FLIR sensors to search for targets but, to simulate the different sensor capabilities in which certain characteristics may be visible using one sensor but not the other (e.g., thermal energy is captured by the FLIR sensor but not by the LLTV), two clusters with targets were only visible in the FLIR window, two clusters with targets were only visible in the LLTV window, and two clusters with targets were visible in both. The same distribution held for the non-targets. The narrow/wide FOV values for the FLIR and LLTV sensors were varied in each experimental session. The values were: 2°:10°; 5°:20°; 15°:35°. In all scenes the FLIR was set to discrete mode while the LLTV was set to continuous zoom with a range equivalent to the discrete FLIR values. An additional scene, where both the LLTV and the FLIR sensors supported continuous zoom with a FOV .5°: 40°, was also completed.

Procedure

Prior to the experimental session, subjects were given three demonstrations and practice sessions – one for each scenario, and were instructed on the features of the display and how to use the equipment. With the exception of the water scenario, participants were to, as much as possible, keep the camera at the head of the aircraft, and search in a 10 o'clock to 2 o'clock pattern, indicated by the bearing pointer located on the interface between the AGTV and FLIR windows (see Figure 1). In the water scenario participants were instructed to direct the camera across the water and search in an up-down pattern while the plane followed the shoreline.

Participants were told the flight path for each scenario, and were shown an example of the target they were to search. During the practice sessions, the experimenter remained present to assist with any difficulties or questions.

Water scenario: In the water scenario, participants were to use the wide FOV setting on the FLIR sensor to search for targets. Upon detecting what they thought might be a target they were to change to the narrow setting to identify the target. If identification was not possible using the FLIR they could revert to the AGTV continuous zoom to determine whether the object was a target or non-target.

Land and retro-reflective scenario: In the land and retro-reflective scenarios FOV was initially set to wide and participants were instructed to use whichever FOV setting (wide, narrow, or continuous zoom) they had at their disposal, and that they felt was most appropriate for the task. As some of the targets/non-targets were visible in only one window, participants were instructed to set the primary/secondary status of the window in which they detected a target to 'primary' before marking the target. The primary/secondary function was an additional task, not used in the other scenarios, and is controlled by a toggle switch on the main joystick. When the target was visible in both windows, either window could be set to 'primary'.

Results

General notes:

i) Arcsine transformations were performed on accuracy scores and were used in all analyses, but percentages are shown in the graphs.

ii) As described in the method section, in an effort to minimize practice effects a number of scenes were created for each of the scenarios. To ensure that the scenes used within each scenario were of equal difficulty, the effect of scene was analyzed independently. No effect was found for any of the scenarios and this variable was subsequently not included in any analysis.

iii) Qualitative data was collected through a sequential record of the events for each participant that occurred during each scenario (e.g., target marked; FOV changed, etc.). The qualitative characteristics of an event, or series of events (e.g., frequency, order), were not statistically analyzed but relevant observations are described in the appropriate discussions as an aid to understanding the way participants performed the search task.

Water scenario

Task Accuracy

In the water scenario, cell means for correctly identified targets (hits) for each FOV, for each subject, were entered into a repeated measures Analysis of Variance (ANOVA) with FOV (2°:10°; 5°:20°; 15°:40°) as a within-subjects factor. No effect of FOV was present ($p > .42$) (mean percent: 2:10 = 52.45; 5:20 = 47.68; 15:35 = 47.22).

Similarly, cell means for non-targets marked incorrectly as targets (false alarms) for each FOV, for each subject, were entered into a repeated measures ANOVA. Again, no effect of FOV was present ($p > .70$) (Mean percent - 2:10 = 1.47; 5:20 = 1.32; 15:35 = 2.75).

Retro-reflective scenario

Task Accuracy

In the retro-reflective scenario, cell means for correctly identified targets (hits) for each FOV, for each subject, were entered into a repeated measures ANOVA with FOV (2°;10°;20°) as a within-subjects factor. As shown in Figure 2, an effect of FOV was present with accuracy increasing as FOV increased [$F(2, 34)$ F = 158.06, $p < .0001$, $MS_e = .038$].

Similarly, cell means for non-targets marked incorrectly as targets (false alarms) for each FOV, for each subject, were entered into a repeated measures ANOVA. No effect of FOV was present ($p > .82$).

Land scenario

Task Accuracy

In the scenario over land, cell means for correctly identified targets, for each FOV, each sensor, and each subject, were entered into a repeated measures ANOVA with FOV (2°:10°; 5°:20°; 15°:35°; and FLIR and LLTV both continuous .5°- 40° zoom) and sensor (LLTV; FLIR; Both) as within-subject factors. Note that for the FLIR sensor FOV was controlled by a discrete function that could be toggled between narrow and wide, with the exception of one level in which a continuous zoom was used. For the LLTV, there was no discrete function and all FOV ranges were controlled by continuous zoom.

The results are shown in Figure 3. The effect of FOV was significant [$F(3, 51) = 15.694$, $p < .0001$, $MS_e = .347$]. The lowest number of correctly marked targets (hits) were observed in the 2°:10° and 15°:35° FOV conditions, with 5°:20° being intermediate, and highest accuracy in the .5°- 40° zoom condition, where both the FLIR and the LLTV sensors were continuous zoom. Scheffé posthoc comparisons revealed that all levels of FOV were significantly different from each other, with the exception of 2:10 and 15:35 conditions. No effect of sensor ($p >.117$) was evident ((mean: LLTV = .45; FLIR = .50; Both = .58), and no interaction of FOV and sensor ($p > .62$).

In a similar analysis for false alarms the effect of FOV approached significance [$F(3, 51) = 2.45$, $p < .075$, $MS_e = .258$]. The results for FOV can be seen in Figure 4. Again, there was no effect of sensor ($p > .643$). Highest false alarm rate was found in the 15°:35° condition, with lowest in the 2°:10° condition, while 5°:20° and continuous zoom (FLIR and LLTV) conditions were intermediate.

Discussion

Water scenario

In the water scenario subjects searched a uniform, large expanse of water looking for targets distributed amongst a series of non-targets. The FLIR sensor was equipped with a discrete FOV wide/narrow function and participants were instructed to use the wide FOV to search for targets, while the narrow setting and the zoom function of the AGTV sensor were to be used for identification purposes. Anticipating that objects of higher luminance would be easier to see than those of lower luminance, and in an attempt to ensure that the FLIR sensor was used to search for potential targets in the scene, the contrast of the targets and non-targets was purposely made higher in the FLIR window than in the AGTV. FOV of the FLIR sensor was varied across sessions while the continuous zoom of the AGTV was always set to a range of .5° to 40°. The general low accuracy found for all FOV conditions suggests that the task was difficult, a characteristic representative of a search over water.

It is not possible to know whether or not participants adhered to using one sensor for searching and the other for identification but qualitative data, showing the functions that were used during the search, suggest that they did. More often than not the AGTV was zoomed-in all the way just prior to marking a target, and zoomed-out all the way after marking. And the data also show that FOV of the FLIR sensor was changed in a similar fashion before and after a target was marked. Thus, the way in which the controls were used suggests that, rather than using one sensor predominantly, participants switched between sensors during the search as instructed. Nevertheless, we cannot be sure which sensor window the participant was actually looking at when a target was marked and consequently it is not possible from this data to reliably determine if the evaluation of FOV for this particular scenario is accurate. It is conceivable that the absence of FOV effects is due to participants primarily detecting the target in the AGTV image.

Of interest is that, overall, participants appear to have found two of the system functions not evaluated in this study helpful to the task, those being auto-track and auto-slew. The auto-track function which locks the camera on a pre-selected location in the scene, and the auto-slew function, which automatically returns the camera direction back to the heading of the aircraft, were both used regularly by most participants, usually in conjunction with the time a target was marked. In general, the frequency of use of different functions available to the operator, such as FOV, auto-track, and auto-slew, decreased as the FOV available to the user decreased. This observation may indicate that the smaller scene area depicted by narrower FOV resulted in a greater need to focus on the search procedure and less on using some of the other functions available.

Retro-reflective scenario

In the search for retro-reflective objects, subjects used the AGTV illuminator beam to search the terrain for targets embedded amongst an equal number of non-targets. One advantage of the AGTV sensor is that it affords long-range detection of retro-reflectivity. Objects with retro-reflective properties that are undetectable from a distance, or are ambiguous using conventional search methods, become relatively easy to detect once captured in the illuminator beam. In field trials retro-reflective tape, on clothing for example, has been detected from as far away as 8 kilometres using the AGTV sensor.

As might be anticipated, the number of correctly identified targets increased as FOV of the beam increased in the retro-reflective scenario. This result suggests that subjects had more chance of capturing, and subsequently identifying targets using the wide illuminator beam than they did with the narrower beam. Supporting this finding is the observation from the qualitative data showing that, in general, the number of actions performed during the search decreased as the FOV available on the illuminator beam decreased. This observation may suggest that the task became more restrictive as the scene area became smaller, thereby reducing the ability to focus on supplementary functions like auto-track and auto-slew.

Although the notion of detection rate increasing with beam FOV might be intuitive it was important to test the logic using sensor imaging techniques. While the sensor interface limits FOV for the operator, the use of an illuminator beam restricts the FOV more so. The beam must pass directly over the object of interest for it to be picked up by the sensor and a narrow beam might miss the target if the search spot is too small to successfully cover the search area before the target moves out of range. On the other hand, a wide beam, although covering the area more effectively, might be too large for the operator to search the area completely. Bear in mind that the area covered by the sensor footprint does not necessarily translate to the area actively searched by the operator (Carver, 1990). Along with the ability to pick up particular characteristics of an object, the illuminator beam serves to focus the operator's attention on a specific section of the search area. If this area is too large the operator may not attend to the entire area, may subsequently fail to search the whole area and, more importantly, may miss a critical target located in some unattended region.

In the current study the wider FOV provided greater detection ability and the absence of an increase in false alarms with increasing FOV might therefore suggest that target identification was also superior with wider FOV. However, the manipulation of FOV of the illuminator beam likely played a minimal role in the process of identification because the wide range zoom-in capability was always available to assist in target identification once a potential target had been detected.

Based on the assumption that, at some point, the width of the beam supersedes the attentional capability of the operator, an upper limit to the benefits of increasing FOV likely exists with respect to target detection. This limit would require further investigation to more clearly determine the point at which performance asymptotes, or declines.

Observations from the qualitative data indicate that participants sometimes used the zoom (.5° to 40°) function on the AGTV, regardless of the FOV of the illuminator beam. Also, like the water scenario, they recurrently used the auto-track and auto-slew functions to aid in the search procedure, although, as already mentioned, the frequency of use of the functions available to them decreased as FOV of the illuminator beam decreased.

Land scenario

In the search over land the LLTV and FLIR windows were used to look for targets embedded in groups of non-targets. In this task FOV was varied using a discrete function (wide/narrow) for the FLIR sensor and a continuous zoom for the LLTV with a range equal to the FLIR discrete values. Also, an additional level was included in which the FLIR sensor was equipped with a continuous zoom, like the LLTV. Furthermore, to evaluate the sensors individually, some of the targets were visible in one window only and some were visible in both windows. Thus, some targets/non-targets were independently represented in each sensor, while others were equally represented in both sensors.

In this scenario, no effect of sensor was observed which, in effect, may translate to no effect of discrete versus continuous mode since, for the most part, one sensor (FLIR) represented the discrete mode and the other (LLTV) continuous zoom. The record of qualitative events supports this observation by showing that both sensors were used throughout the task, thereby equalizing the chance of finding targets in both sensor windows. The absence of an effect of sensor suggests that there was no benefit to having targets appear in both windows as compared to one window but care must be taken not to generalize these results too broadly. Conditions present in the real world, in which the capabilities of both sensors are essential, were not simulated here. Nevertheless, the results from this study clearly show that, under some conditions, having more than one window available to the operator is of no significant benefit.

Combining the hit and false alarm data, few targets were marked and few mistakes made when using the narrowest FOV (2°:10°) implying that targets were hard to find using this range. In contrast, the low hit and high false alarm rate for the 15°:35° range suggests that the wide FOV setting in this condition may have been suitable for detecting possible targets but that the narrow setting was not adequate to make identification accurate. Likely the narrow setting of 15° did not provide sufficient magnification, leaving the subject unable to effectively judge whether the object was a target or a non-target. The false alarm rate is important because time taken to investigate objects that are not targets reduces the chance of the SAR operation being successful. Best performance was observed for the intermediate FOV range of 5°:20° and for the FLIR/LLTV combined continuous zoom of .5°:40°. In both these conditions a relatively high number of targets were correctly identified and few non-targets were incorrectly mistaken as targets. Performance like this suggests that these ranges provided appropriate FOV to effectively execute all phases of the search task. One FOV was wide enough for detection purposes, capturing a large number of possible targets, and another was suitably narrow for the operator to successfully discriminate targets from non-targets upon closer scrutiny.

According to the record of events that occurred during each scenario, most participants used the widest FOV for the majority of the search, regardless of which range was available, and changed from wide to narrow levels just prior to marking a target, returning to the widest FOV after the target was marked. This was true for the discrete mode of operation on the FLIR sensor but it was also true for the continuous zoom function on the LLTV. The qualitative data also suggests that the LLTV continuous zoom may have been used differently depending on the mode on the FLIR that it was used in conjunction with. When the FLIR supported a discrete mode, and the LLTV continuous zoom, the qualitative data suggests that the continuous zoom may have been used more like a discrete function. Participants tended to change FOV quickly and directly, using only the narrowest and widest levels available and seldom pausing at intermediate levels. A similar pattern was true for the water scenario where the AGTV continuous zoom was always coupled with a discrete mode for changing FOV. In contrast, when both sensors supported continuous zoom, the zoom-in and -out actions were steadier and more gradient, and more representative of the customary operation of a continuous zoom. This observation, if accurate, is important. If the continuous zoom function available to the operator is not used as such when it is coupled with a second sensor that supports a discrete FOV mode, the expense and added complexity to the system may not be justified. It is possible that the way the continuous zoom was used in this study was a result of the limited range available, at least in the land scenario, where the FOV range on the continuous zoom matched the narrow/wide values on the discrete FLIR. More benefit may have been gained from the zoom if the range had been wider than the discrete function range, although the qualitative data from the water scenario, where this was the case, suggests otherwise. Nevertheless, the issue remains worthy of further investigation.

Like the water and retro-reflective scenarios, the qualitative data also showed that the auto-track and auto-slew functions were used regularly throughout the task, and the frequency of using all functions available dropped with smaller FOV values.

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Experiment 2

The two conditions that demonstrated highest accuracy for target detection in the land scenario were the 5°:20° and .5°: 40° ranges. In the 5°:20° condition FOV on the FLIR was changed by using a discrete, narrow/wide, mode of operation and on the LLTV by a continuous zoom function. In the .5°: 40° condition both sensors supported continuous zoom. Accuracy between the two conditions was higher in the FLIR/LLTV combined continuous zoom condition, though false alarm data was no different between the two. However, it is unclear whether the superior performance seen for continuous zoom resulted from the wider range of FOV or whether it was a function of having continuous zoom control available on both sensors.

Experiment 2 was designed to independently test the functionality of the discrete versus continuous zoom methods of changing FOV. As discussed earlier, if the ability to change FOV is available, SAR technicians will usually opt to use the wider view for detection and change to a narrower FOV for closer inspection when a potential target is spotted. However, switching between one FOV and another changes the size of the visible area as well as the resolution and magnification of the picture. Bear in mind that the scene is constantly moving and, if the target is not relatively well centered in the image at the time of switching to a narrower FOV, it might be lost from view. Furthermore, other potential targets might be missed while focussing on a specific area using the narrow FOV. On the other hand, switching from narrow to wide limits the capability for close inspection of a target and reduces the chances of successful discrimination and identification. All in all, there are a number of variables associated with FOV that might affect the outcome of a search mission. Timing is critical, and the method by which changing FOV is accomplished might affect the ability, and possibly the inclination, of the operator to make that change. Keeping in mind that the qualitative data from Experiment 1 suggest that a zoom function may not always be used in a characteristic fashion, by and large a continuous zoom is represented as a gradient and the operator is able to progressively zoom-in or out and examine a gradually changing image. In contrast, discrete mode allows the operator to quickly change between two very different views and promptly shift from search to scrutiny. Whether one of these methods of changing FOV is more effective than the other for search and rescue purposes using a sensor surveillance system is not known, although Carver (1990) found a slight benefit for a discrete method of changing FOV over continuous zoom for detection only and for an automated slewing pattern, not manual.

The task in Experiment 2 was a search task using a scene similar to the land scenario in Experiment 1. Unlike the land scenario in Experiment 1 however, only the FLIR sensor was used and only one FOV range. Participants completed separate search missions using either a discrete method for setting FOV that toggled between 5° and 20°, or a continuous zoom function with a range of 5°:20°. The span of 5° and 20° was chosen because this range was the most effective in Experiment 1, producing a high hit rate with relatively few false alarms.

Method

Participants

Sixteen subjects participated in a 60-minute session. The subjects were employees of DRDC Toronto, or were recruited from the general public. Participants were given a near-vision acuity test and a contrast sensitivity test, and all had normal or corrected-to-normal vision.

Apparatus

The apparatus was identical to Experiment 1.

Stimuli

Stimuli were the vehicles described in the land scenario in Experiment 1. The specific scenes used were also from Experiment 1. Six target stimuli were embedded in each scene along with 30 non-targets. Targets and non-targets were organized in 12 clusters so that a target was present in six of the clusters and absent in the remainder.

Procedure

Prior to the experimental session, subjects were shown two demonstrations and participated in two practice sessions – one using the discrete method of changing FOV and one using the continuous zoom function. The practice session for each given method took place immediately before the experimental session. Participants were taught the features of the display and how to use the equipment. To simulate an actual SAR operation they were instructed to, as much as possible, keep the camera at the head of the aircraft, and search in a 2 to 10 o'clock pattern, indicated by the bearing indicator between the two sensor windows (see Figure 1). Participants were told the flight path of the aircraft and were shown an example of the target. During the practice session, the experimenter remained present to assist with any difficulties or questions.

Results

General Notes:

i) As in Experiment 1 arcsine transformations were performed on scores and these values were used in all analyses.

ii) Also, no effect of scene was found and consequently this variable was not included in the analyses.

iii) As in Experiment 1 qualitative data was collected by recording the use of controls and functions for each participant throughout each scenario.

Task accuracy

Cell means for correctly identified targets, for each method (discrete: continuous), for each subject, were entered into a repeated measures ANOVA with method as a within-subjects factor.

The effect of method approached significance for correctly identified targets [$F(1,15) = 3.27$, $p < .091$, $MS_e = .025$]. Hit rate was slightly higher when subjects used the continuous zoom (M = .76) compared to performance using the discrete method (M = .67).

A similar analysis was performed on false alarms where no effect was observed ($p > .13$), however, together with the hit data, the pattern of means (M = .024 for continuous; M = .031 for discrete) supports the continuous method of changing FOV. Using the continuous zoom false alarm rate was lower and hit rate higher.

Discussion

The scenario in Experiment 2 used one range of FOV to evaluate different modes of operation for changing FOV while searching for targets in a land based scene. The range of 5°:20° was chosen because, in Experiment 1, this range produced the largest number of hits and a relatively small number of false alarms. However, in Experiment 1, each scenario included two ways of changing FOV, and the method used depended on the sensor window in use, continuous mode for the LLTV and discrete for the FLIR. In Experiment 2, only one window was visible to the participant, that being the FLIR window, and the two modes for changing FOV were divided across two scenarios carried out separately.

Although the difference between methods was not significant, the data suggest a trend toward continuous zoom over discrete. The number of correctly identified targets was higher when continuous zoom was used the number of non-targets incorrectly marked as targets lower. The trend suggests that a difference in search performance exists between using continuous zoom and using a discrete method of changing FOV. The advantage is unlikely to be consistent across search paradigms however, and benefits for either method may emerge depending on the characteristics of an individual search operation, such as the tasks involved in the search (Williams,1977), environmental conditions, and the terrain encountered (Scalon,1977). Carver (1990) for example, found a 7% benefit for using a discrete method of changing FOV in a search task with automatic slewing. Although the improvement was only seen for detection, not recognition, the study, together with our results, serves to illustrate that the decision of whether to opt for continuous zoom or discrete FOV is not an easy one.

As in Experiment 1, the qualitative data from this experiment indicated that most of the search was conducted using the widest FOV available, and participants tended to zoom-in or change to the narrower level of FOV just prior to marking a target, and return to the wider setting immediately after marking a target. This was true for both the continuous zoom and discrete methods. Again, in the continuous mode the boundaries of the range of FOV were more commonly used than any intermediate values. The event data also revealed that functions like auto-track and auto-slew were frequently made use of throughout the task.

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Conclusion

The current study was designed to investigate performance on search tasks using a multi-sensor surveillance system such as the ELVISS. Three search scenarios were created to assess the impact of FOV of the sensors on search performance. The task in each scenario involved searching a frame of imagery displayed on an interface, slewing the sensor toward terrain believed to contain a target, and identifying and designating the object as a target.

Three different airborne search scenarios were simulated in this study: one over a large area of water, one over land, and one specifically designed to search for objects with retro-reflective properties. The scenarios were designed to consider the diversity of the search and rescue environment while assessing the impact of the choice of FOV as it relates to the capabilities, and possible limitations, of a sensor system such as ELVISS. Each scenario was evaluated independently.

Success of a search mission using a sensor surveillance system relies on input from two search patterns, one directed by the flight path of the aircraft, and another created by the operator directing the camera and searching the sensor image. Both must work together to provide adequate and appropriate information to optimize target localization. The operator has no direct control over the aircraft and must communicate with the navigator or pilot to alter the course of the aircraft. While covering enough ground area so that there is a high probability that the target will fall into view in the interface sensor window, the speed of the aircraft, or slew rate of the sensor, must not be so rapid as to jeopardize the likelihood of finding a target. Furthermore, searching for potential targets and then determining whether they are actual targets are two different tasks, each benefiting from different image magnification. The operator must select the appropriate magnification while considering the consequences of related changes in resolution and FOV.

In general, the findings from these experiments suggest that the most appropriate FOV for search tasks using displayed imagery depends on factors related to the search itself. These include: the capabilities and characteristics of the sensor, the characteristics of the target, the type of ground cover and complexity of the terrain, the tasks involved in the search, and knowledge of where the target is likely to be located. For example, performance improved as FOV increased when searching for retro-reflective targets with the illuminator beam. Although this function is likely to asymptote at some point, it nevertheless, generally suggests a linear relationship between FOV and target acquisition. In contrast, in a search that encompassed a wide area where the targets were less salient, an intermediate FOV was more effective. The method by which FOV was changed was also investigated and implicated as a factor in the outcome of a search operation. Although our results point to supporting a continuous zoom over a discrete mode, this finding may vary as a function of the characteristics associated with the search. Further to this was the observation from the qualitative data, that the continuous zoom function may be used differently when it is coupled with another sensor that supports a discrete method of changing FOV. This point, along with the level of FOV at which the relationship between target acquisition and width of the AGTV illuminator beam asymptotes, or declines, and the significance of scene and sensor characteristics as they relate to search performance using displays with limited FOV, will be addressed in future research.

Recommendations

It is recommended that each sensor be equipped with the capability to switch between narrow and wide FOV so that both the detect and identify components of the search task can be effectively achieved. The wide FOV should be greater than 10° but whether the mode of changing FOV should be continuous zoom or a discrete wide/narrow function is unclear. Results from this study suggest that further research is warranted in this area.

Automating specific functions is integral to the sensor surveillance system because of its complexity. Thus, it is recommended that further research determine the prime candidate functions that could be automated and the impact of automation on operator performance.

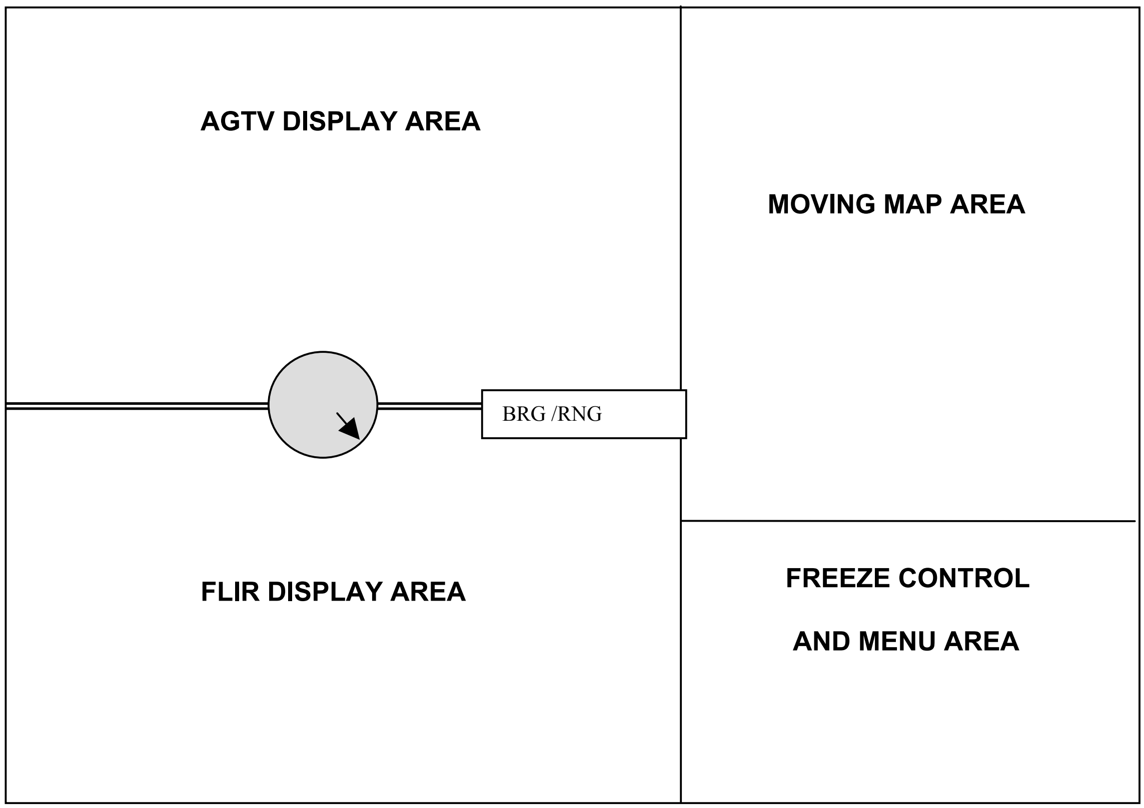

Figure 1. *Schematic representation of the ELVISS interface.*

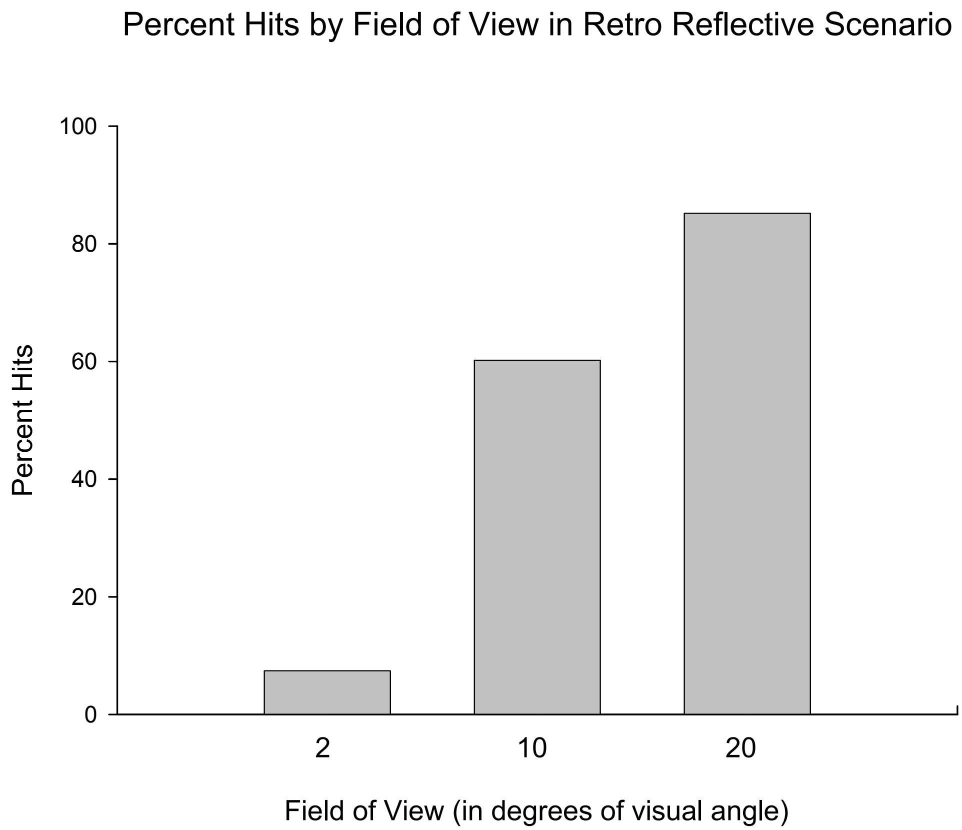

Figure 2. *Experiment 1 – Percentage of hits in the retro-reflective scenario as a function of field of view (2; 10; 20).*

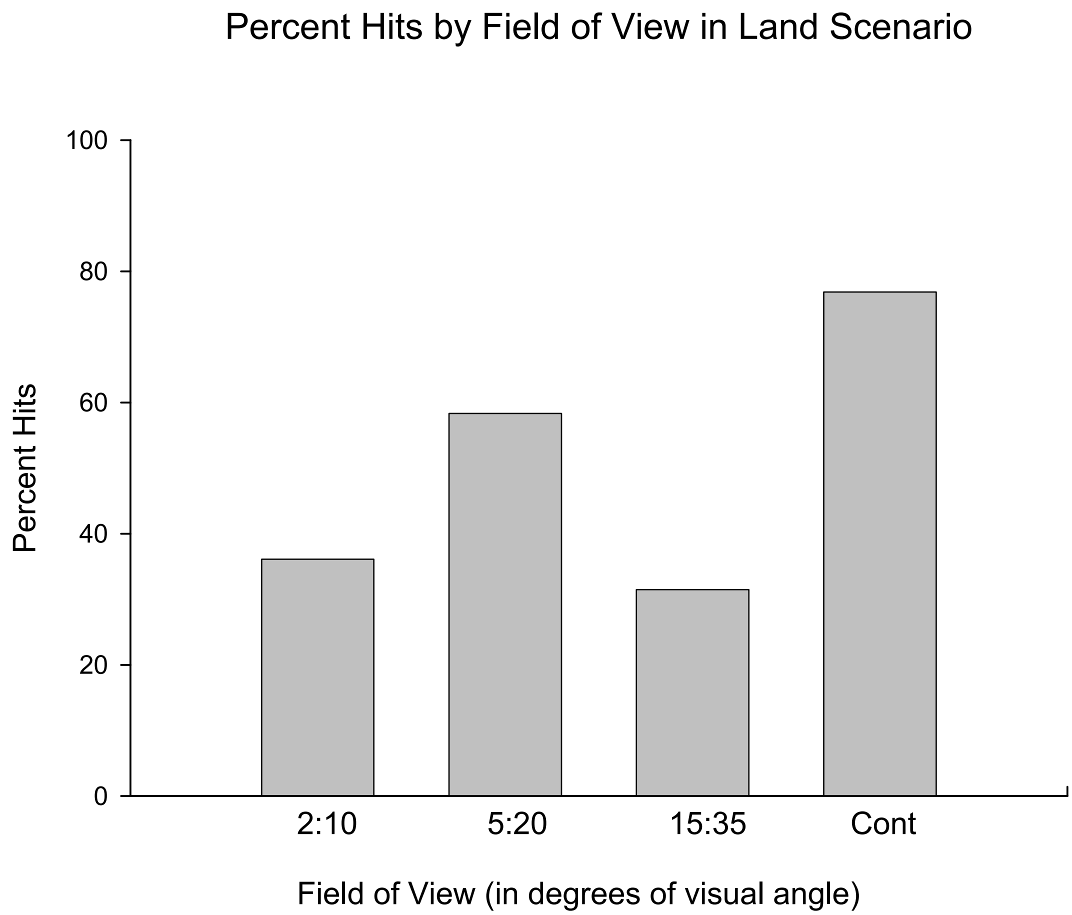

Figure 3. *Experiment 1 – Percentage of hits in the land scenario as a function of field of view (2:10; 5:20; 15:35; Continuous).*

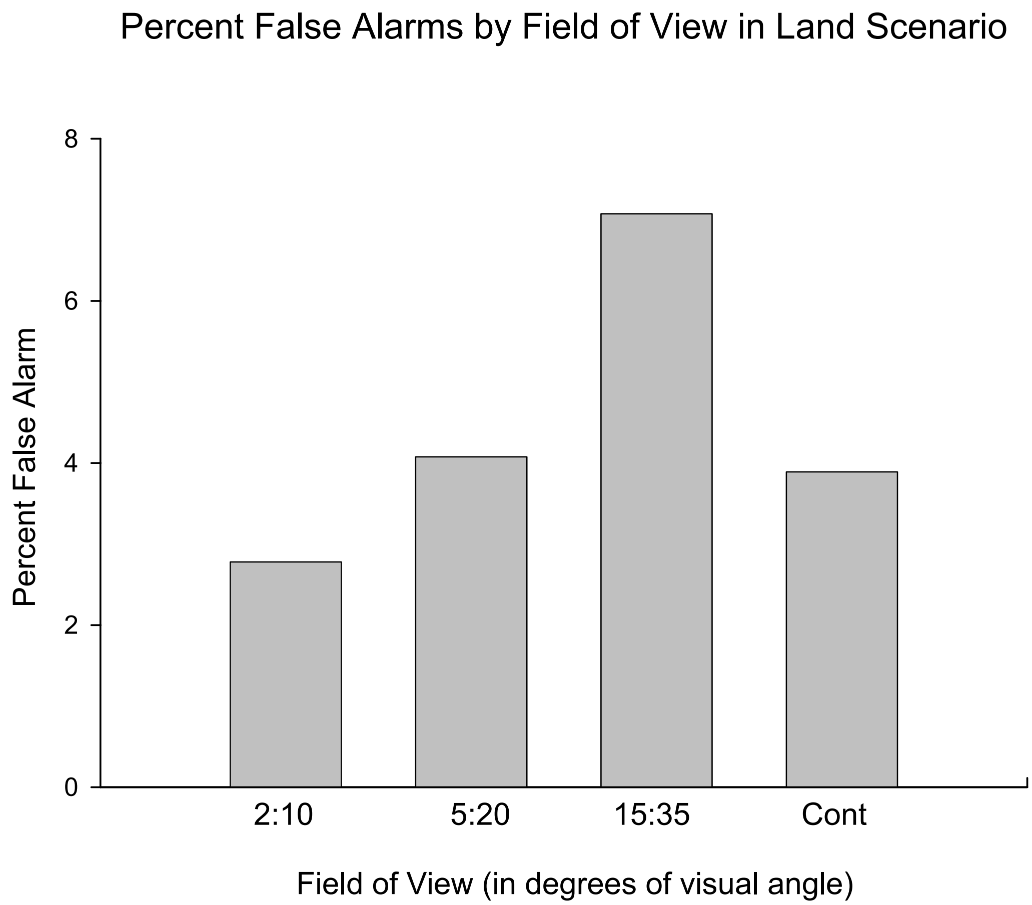

Figure 4. *Experiment 1 – Percentage of false alarms in the land scenario as a function of field of view.*

Table 1. *Luminance values of targets and terrain in the water scenario*

OBJECT	AGTV (WITHIN BEAM)	AGTV (OUTSIDE BEAM)	FLIR
Terrain	1.20	0.94	7.12
Targets	3.23	2.14	9.505*

*Average across 2 different areas in the target.

** Average across 5 different areas in the terrain.

Table 2. *Luminance values of targets and terrain in the retro-reflective scenario*

OBJECT	AGTV (WITHIN BEAM)	AGTV (OUTSIDE BEAM)	FLIR
Terrain	1.27**	.986**	N/A
Targets	3.12	2.12	N/A
Retro reflective patch	5.52	N/A	N/A

*Average across 2 different areas in the target.

** Average across 5 different areas in the terrain

Table 3. *Luminance values of targets and terrain in the land scenario*

OBJECT	AGTV (WITHIN BEAM)	AGTV (OUTSIDE BEAM)	FLIR
Terrain	N/A	1.706	22.14**
Hummer	N/A	7.23	13.21
Truck	N/A	4.97	12.9
Leclerc Tank	N/A	12.3	13.3
T 72 Tank	N/A	13.1	12.9

*Average across 2 different areas in the target.

** Average across 5 different areas in the terrain

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List of symbols/abbreviations/acronyms/initialisms

AGTV	Active-Gated TeleVision
AOI	Area of Interest
CCD	Charge Coupled Device
DND	Department of National Defence
DRDC	Defence Research and Development Canada
ELVISS	Enhanced Low-light Level Visible and Infrared Surveillance System
FLIR	Forward-Looking InfraRed
FOV	Field Of View
HMOS	Helmet-Mounted Oculomoter System
LLTV	Low-light Level TeleVision
SAR	Search and Rescue

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14. ABSTRACT

(U) Search performance using optical imaging systems with restricted viewing area was investigated using a prototype interface and controls of the airborne Enhanced Low-light Level Visible and Infrared Surveillance System (ELVISS). Three different search environments were simulated, one over water, one over land, and one designed specifically to search for objects with retro-reflective properties. Field of view (FOV) of the images from the two ELVISS sensors, a Forward-Looking InfraRed sensor, and an Active-Gated TV was varied. The study suggests that the most effective FOV for search using imaging systems depends on the type of search and/or the sensor mode employed. When using a laser illuminator beam to search for targets with retro-reflective properties, more targets were accurately identified when FOV was wide (20°) than when it was narrower (2°). In other tasks, when the beam was not active, a narrow/wide FOV range of 5° and 20° was more effective than lower (2°:10°) or higher (15°:35°) viewing fields.

(U) On a effectué une étude sur l'exécution de tâches de recherche à l'aide de systèmes d'imagerie optique à champ de vision limité en se servant d'un prototype d'interface et de commandes du système perfectionné de surveillance à intensification de lumière visible et à infrarouge (ELVISS), installé à bord d'aéronefs. Trois environnements de recherche différents ont été simulés : un au?dessus de l'eau, un au?dessus du sol et un autre conçu spécialement pour la recherche d'objets ayant des propriétés de rétroréflexion. On a fait varier l'angle de champ des images obtenues avec deux capteurs ELVISS : un capteur infrarouge à balayage frontal et un capteur de télévision commandée par portes actives (AGTV). Les résultats de l'étude portent à croire que le champ de vision le plus efficace pour la recherche à l'aide de systèmes d'imagerie dépend du type de recherche effectué et/ou du mode utilisé pour le capteur. Lorsqu'on utilisait un faisceau d'illuminateur laser pour la recherche de cibles ayant des propriétés de rétroréflexion, on a identifié avec précision un plus grand nombre de cibles avec un champ de vision large (20°) qu'avec un champ de vision étroit (2°). Dans d'autres tâches, lorsque le faisceau n'était pas actif, une combinaison de champs de vision de 5° (étroit) et 20° (large) était plus efficace qu'une combinaison inférieure (2° et 10°) ou qu'une combinaison supérieure (15° et 35°).

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) field of view; target detection; airborne search; optical imaging systems; retroreflective; continuous field of view; discrete field of view